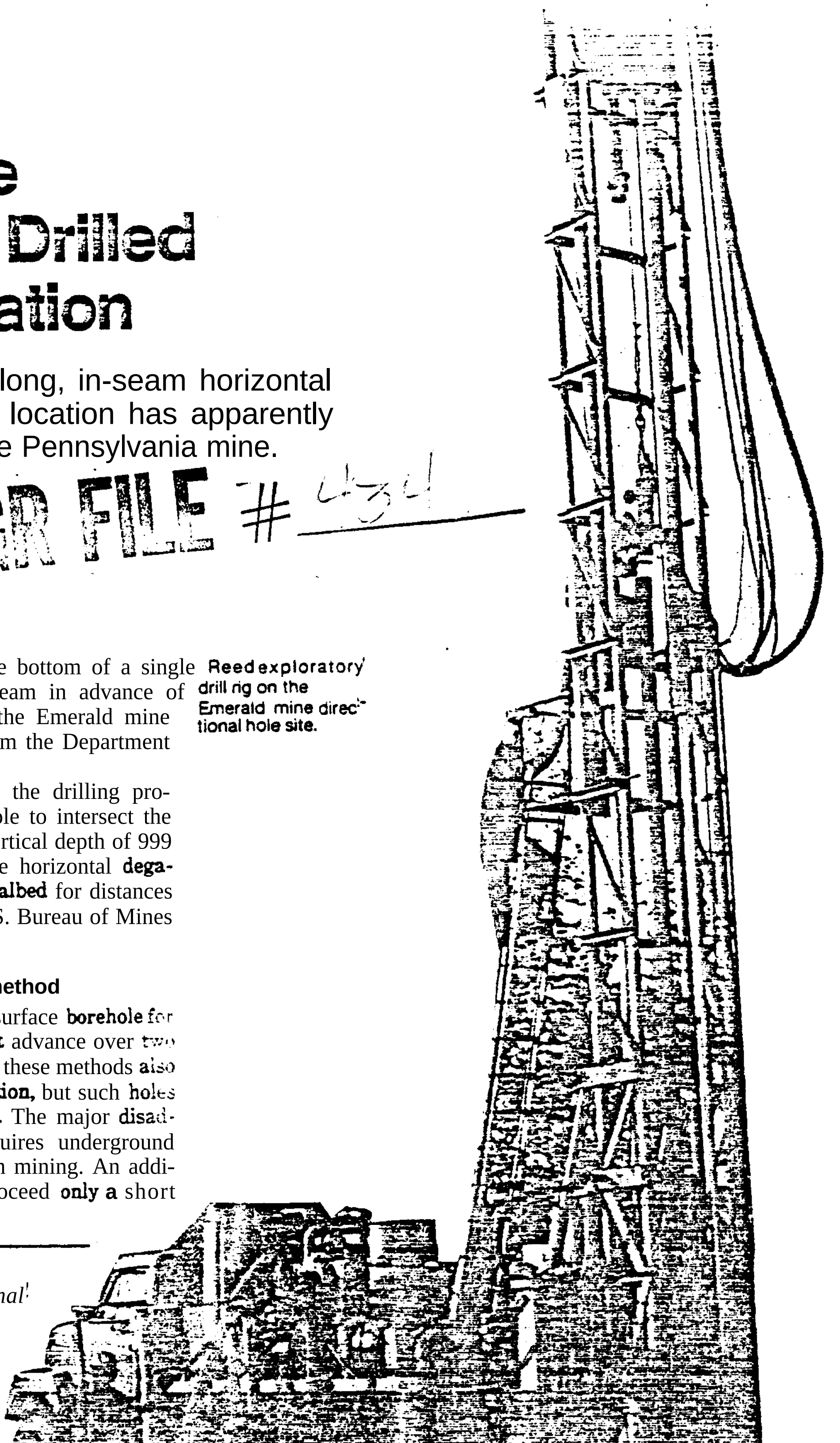
Multi-leg Hole Successfully Drilled for Degasification

A technique to drill several long, in-seam horizontal holes from a single surface location has apparently proven itself successful at one Pennsylvania mine.

Verne R. Nesvacil



Reed exploratory drill rig on the Emerald mine directional hole site.

Horizontal holes can be drilled from the bottom of a single directional hole, to degasify a coal seam in advance of mining. Contractor Harold F. Scott at the Emerald mine near Waynesburg, Pa, under contract from the Department of Energy, was the first to succeed.

Eastman Whipstock Inc implemented the drilling program, which called for a directional hole to intersect the Pittsburgh seam horizontally at a true vertical depth of 999 ft. From that point of intersection, three horizontal degasifying holes were drilled through the coalbed for distances of 1,767 ft, 3,207 ft and 2,993 ft. The U.S. Bureau of Mines provided technical support.

Not the first, but maybe the best method

Horizontal drilling from a directional surface borehole for degasification may represent a significant advance over two conventional but related methods. One of these methods also employs horizontal holes for degasification, but such holes are drilled from underground locations. The major disadvantage to this method is that it requires underground access and facilities which interfere with mining. An additional drawback is that drilling can proceed only a short distance ahead of mining.

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A team of technicians prepare to hydraulically stimulate a dewatering hole as a means to increase the seam's permeability to gas, water flow.

The other conventional method uses a number of vertical holes which are drilled from the surface to the seam and then hydraulically stimulated to drive out the methane. Though this procedure eliminates problems associated with underground horizontal holes, it does require expensive multiple wellsites and is subject to various maintenance and production problems.

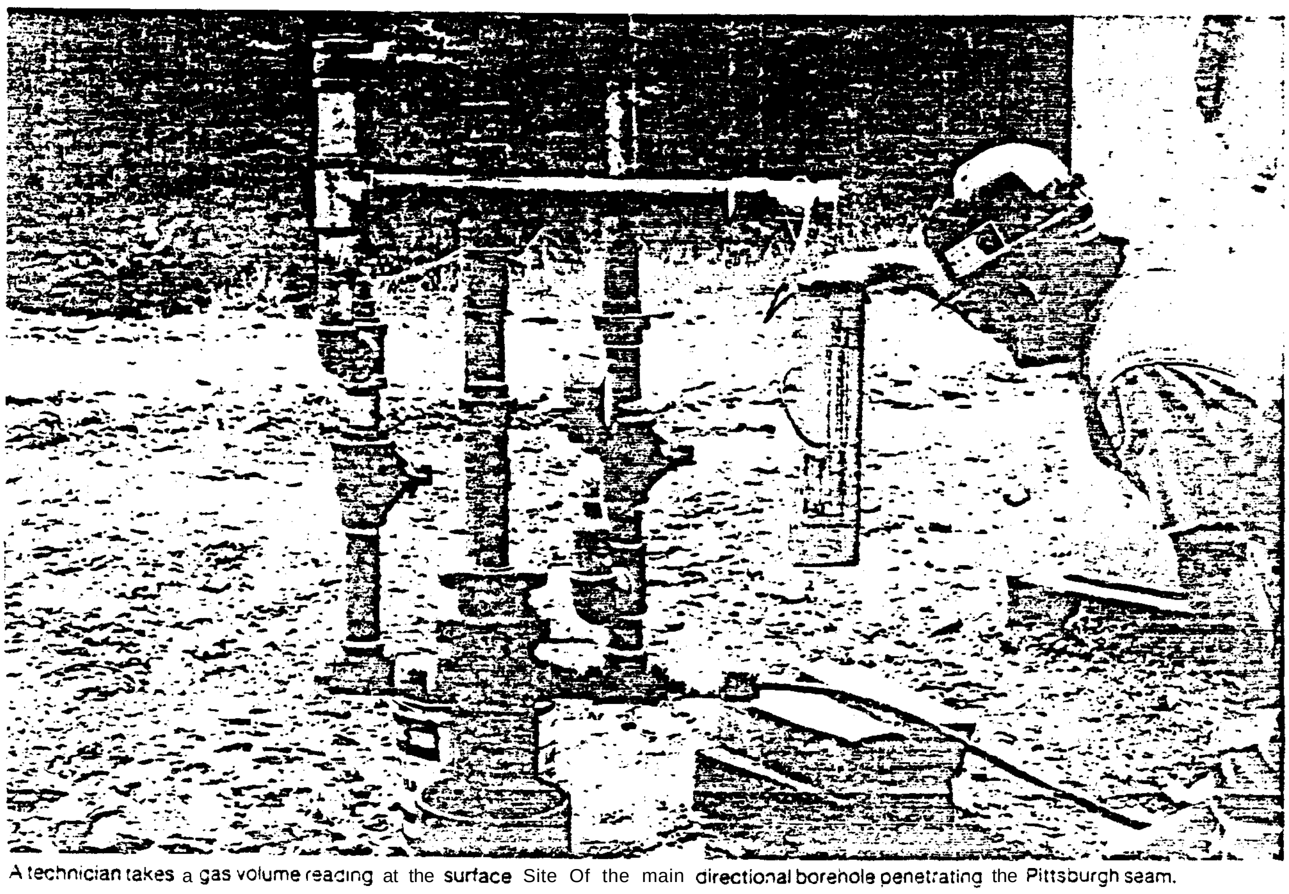
The use. of horizontal degasification holes drilled from the surface potentially embodies the best aspects of both conventional methods without the drawbacks of either.

As the Emerald mine project began in September, 1978, two major questions remained unanswered. First, could horizontal holes be drilled from a surface directional borehole with sufficient precision to adequately degasify a coal seam? Secondly, could the holes be drilled with sufficient speed to make these techniques economically practical?

Two previous attempts

Two similar but unsuccessful projects had already been attempted. In the first project, in 1973, three horizontal holes were drilled, but none penetrated the seam for more than 450 ft. In addition, a downhole sucker rod pump was unable to dewater the coalbed from a horizontal position. Consequently, water from the formation restricted the gas flow and brought the project to an end.

The second project began in late 1975. Here, the coal seam was not continuous enough to demonstrate the practicality



A technician takes a gas volume reading at the surface Site Of the main directional borehole penetrating the Pittsburgh seam.

of horizontal drilling in degasifying a coalbed. Directionally drilled holes simply ran out of coal and the project ended short of its goal.

Initial drilling program

Overall experience gained in these earlier efforts was particularly useful, however, in developing the drilling program for the Emerald project The first stage of the project, which preceded the directional drilling, called for a corehole, dewatering hole and seven monitoring holes to be drilled vertically.

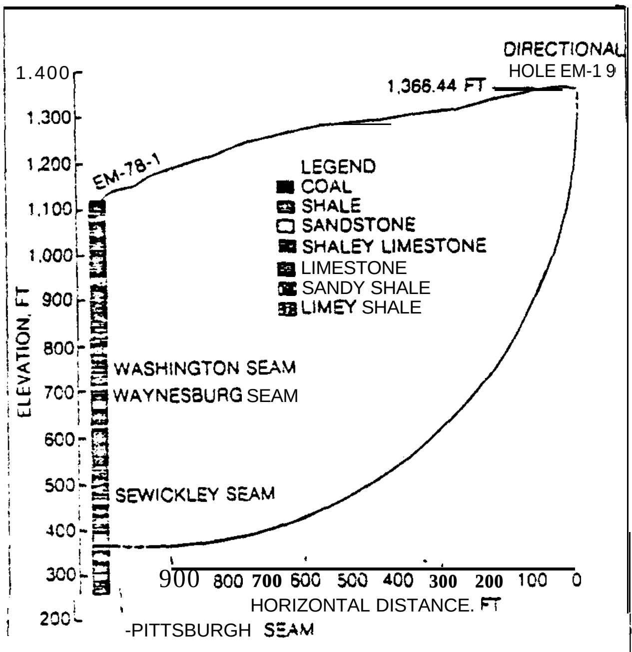
The corehole was drilled at the point where the main directional hole would intercept the seam. Its purpose was to determine the thickness and depth of the coal and collect other geologic data

The vertical dewatering hole was drilled adjacent to the corehole, and was hydraulically stimulated before directional drilling began.

The seven monitoring holes, all drilled within the area to be degasified, were vital in measuring the extent of degasification in specific areas of the coal seam. These holes could be used for dewatering in the event the main dewatering hole would fail and could also be used for short periods of gas production for test purposes, or even long term production if circumstances warranted.

Main directional hole

Before horizontal drilling began, a 3-in.-dia hole was directionally drilled in an arc. The hole began vertically for the first 50 ft., then built angle at the approximate rate of 6 deg per 100 ft. After the hole had reached its target depth of 999 ft, it was reamed to 8% in.



A sectional view of the slant-hole well path with the geologic column as found at the Emerald mine near West Waynesburg, Pa. (Courtesy USBM).

Maintaining directional control in implementing the horizontal drilling aspect of the program was inherently more difficult than in conventional. oilfleld drilling, where directional drilling is routine.

Normally, an oil or gas well is drilled to hit a target circle about 300 ft in dia which lies within the formation believed to contain oil or gas. Based on the target's direction, horizontal distance, depth and local geology, a well plan is developed to project the most efficient course to intercept the target. Though it is desirable to follow the well plan as closely as possible, an oilfield well normally deviates somewhat from this projection in reaching its target. In fact, when the target is located in a large formation and directional control problems are encountered, the size of the target zone can be, and often is, increased

Five factors made drilling at the Emerald mine more complex than conventional oilfield drilling:

- Since the target was one continuous horizontal expanse of coal, the holes had to stay within their target continuously as they were drilled. In this sense, the normal oilfield distinction between wellpath and target did not exist.
- The target was a 6-ft-thick coalbed, not a comparatively large, 300-ft-dia circle. There was little margin for error in directing horizontal boreholes through the seam.
- The exact location and dip angle of the coalbed target was not known at any specific point along the length of coalbed.
- The horizontal extent of the coalbed was also unknown.
- The small 2⁵⁄₁₆-in. drill pipe made directional control far more difficult than if larger, oilfield-size pipe would have been used. The smaller, more limber pipe increases the tendency of a borehole to wander from its intended path.

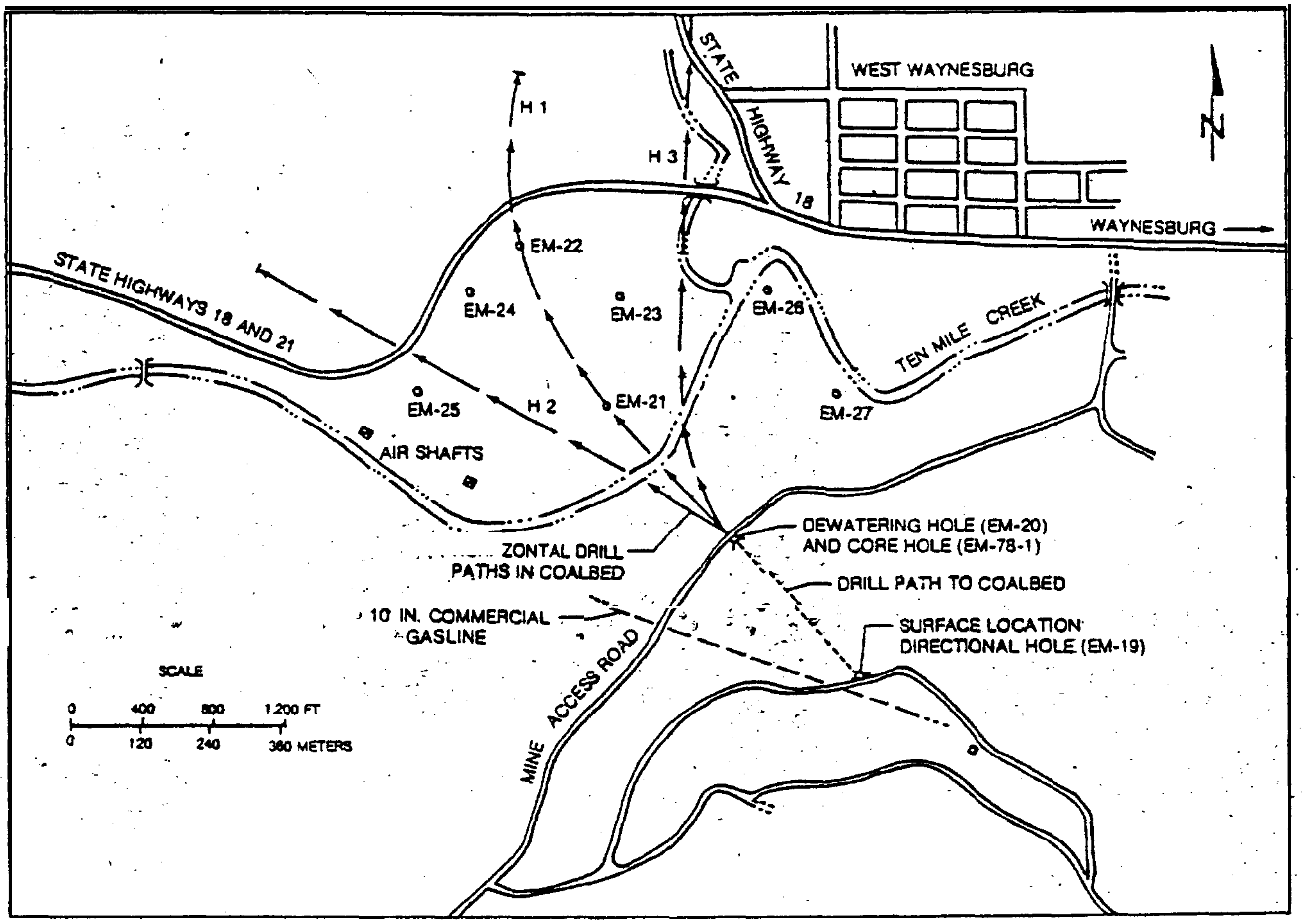
The directional techniques necessary to drill under these conditions evolved in response to specific problems encountered in the project. These techniques were applied with increasing efficiency on each of the three horizontal legs of the borehole.

Sidetracking

When drilling the first leg, the wellbore frequently exited the top or bottom of the coal seam because of directional control problems and the uncertainty of the actual location and disposition of the coal bed. At first, when the drilling assembly left the coal seam (indicated by a dramatic decline in the drilling footage rate caused by the harder rock above or below the coal), the toolface was oriented back to the coal and drilling continued.

Unfortunately, this procedure established drilling trends that the bent housing's small deflection and the limber drill string could not counteract. For example, if the borehole exited the top of the coal seam, the toolface would be oriented downward. This would put the wellbore on a trajectory that would send it through the bottom oi the coal. Then, orienting the face upward would send the drilling assembly through the top of the coalbed before a horizontal path could be re-established (see page 148, top). This led to excessive drilling time in the first horizontal leg and a wellbore that was outside the coal over the greater part of its course.

So-called open-hole sidetracking proved to be a much more effective means of returning the wellbore to the coal



Plan view of drill sites and the slant and horizontal-hole well paths at the Emerald mine. (Courtesy USBM).

seam. in this technique, the assembly was pulled back beyond the point of exit and the toolface re-oriented to drill within the coalbed. No cement plug was set (In oilfield drilling, a cement plug is normally set during a sidetrack to prevent the drill string from re-entering the spur during subsequent trips into the hole with the drilling assembly. In the Emerald mine project; cement may have clogged the boreholes, making the eventual removal of methane impossible. In addition, the added cost of cementing at each sidetrack would have made this practice too expensive.) To avoid re-entering the uncemented spurs, Eastman Whipstock kept a complete log of survey data for each sidetrack location, including measured depth, survey depth, inclination direction and toolface setting. With this information, the toolface would he oriented at each sidetrack so that the assembly would be guided away from the spur and into the main hole when returning from a trip.

The open-hole sidetrack technique proved decisive in speeding horizontal drilling. After discovering the advantages of this technique, Eastman Whipstock routinely performed open-hole sidetracks at Emerald.

Optimum survey intervals

Optimum spacing between downhole surveys also was determined from experience gained during the project In general, very close surveys provide a more accurate picture of the well's path and make it easier to guide the well on its intended path. However, drilling must be stopped to take a survey, and delays increase drilling costs.

Because survey downtime at the Emerald mine averaged approximately one hour per survey station, it was important to identify the maximum interval between surveys that would still allow adequate directional control. After experimenting with 10, 20 and 40-ft intervals, it was found that 40-ft intervals provided the optimum blend of drilling economics and directional accuracy. Surveys were also taken when the toolface setting was adjusted.

Projecting dip angle

Determining the exact location of the coalhed and its variations in dip angle also complicated the directional drilling operation. Before drilling began, the location of the coalbed was known in the area of the vertical corehole and-more precisely-at those points where the vertical monitoring holes were located. Based on these known locations, a pre-drilling estimate of coalbed dip angle was developed.

However, at various points during drilling it was found that this original estimate and the actual location of the coalbed were at variance. For such situations, Eastman Whipstock determined the position of the seam by calculating its dip angle from two survey points—one where the assembly exited the coal and another where it re-entered.

Knowing a point of coalbed exit and re-entry, it was possible through triangulation to determine the dip angle for the coalbed. This angle was projected immediately forward of drilling as a revised estimate of coalbed dip angle. The toolface could then be oriented to remain within the coalbed through its anticipated path.

The acid test

When the drilling assembly left the coal seam, another technique was used to determine whether it exited from the top or the bottom.

As mentioned, a dramatic decline in the drilling rate was an immediate indication that the assembly had left the soft coal and entered the hard formation. However, this slowdown in drilling could occur both above or below the coal seam.

The core sample revealed that a portion of the coalbed was situated beneath a layer of shale containing an extremely thin layer of calcite and above another layer of shale not containing calcite.

In the initial stages of drilling each leg, an acid test, using dilute hydrochloric acid to detect calcite in the cuttings, could distinguish between the upper and lower formations and thereby determine whether the assembly had exited through the top or bottom of the seam. The toolface could then he oriented to re-enter the seam, or an open-hole sidetrack could be planned to keep the main borehole within the coal.

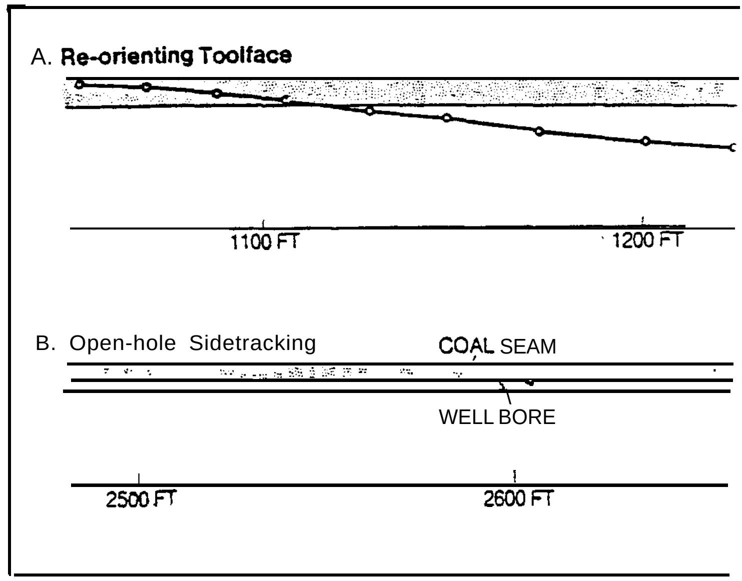
This method was useful only as long as he seam was located between two different formations. As drilling progressed, the calcite in the upper layer of shale disappeared. The acid teat was then abandoned, in favor of analyzing drilling trends to establish the borehole's location relative to the coal.

When penetration rates dropped and sky data indicated a pattern of angle build, it was assumed that the trend continued to the point of exit and that the borehole was located above the seam. The appropriate re-orientation was then made. Siiilarly, a trend of angle-drop was assumed to indicate a bottom hole location below the coalbed.

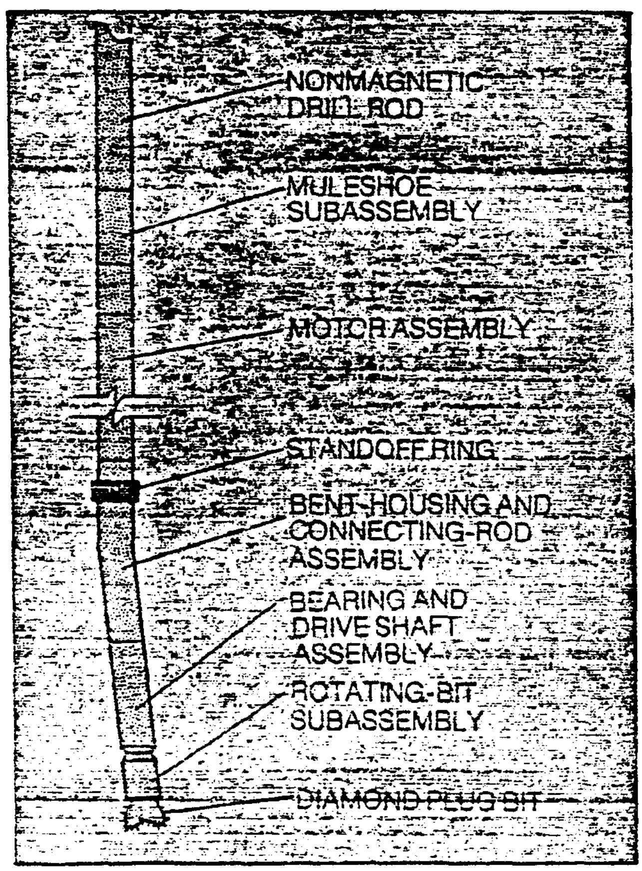
A pattern of progressive efficiency

Throughout the project, directional control problems were met with a series of progressively more efficient solutions. The second phase of horizontal drilling was completed in half the time of the first, while the third phase of drilling was completed in half the time of the second. The shortest hole, the first drilled, reached a horizontal distance of 1,767 ft in approximate19 two months. The second was drilled to a distance of 3,207 ft in approximately one month. The third and final hole was drilled a distance of 2.993 ft in just two weeks.

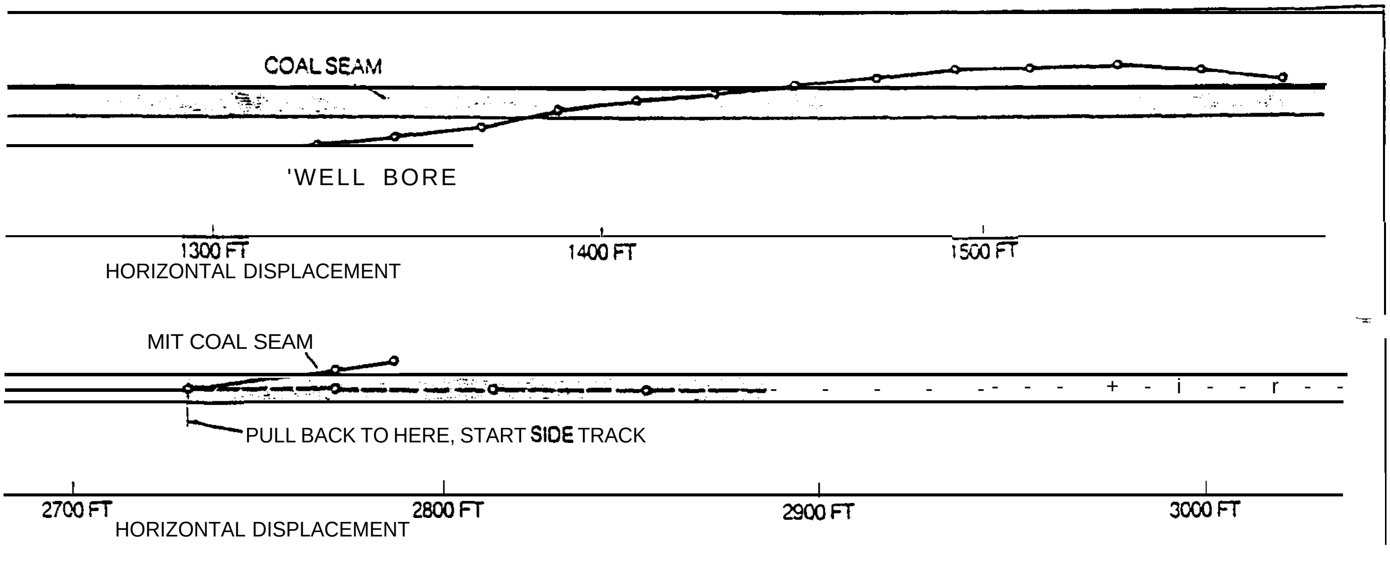
Directional control techniques identified and developed during the Emerald project can greatly enhance the overall



Above are two techniques used in attempting to keep the drilling assembly inside the coal seam. Initially, when the well bore left the seam, the toolface of the assembly was re-oriented back into the coal (A). This was not very successful. Open-hole sidetracking (b) was better. When the well bore left the seam, the drilling assembly was pulled back into the coal and then oriented to sidetrack the spur.



Above is the basic design of the tool assembly employed to drill and to orient the degasification holes. (Courtesy USBM).



Principles of Directional Drilling

Basic directional drilling principles were applied at the Emerald mine to control the main hole and the three horizontal legs.

A bend or angle incorporated into the drilling assembly is one means of maintaining directional control over the borehole. As drilling is underway, the bend in the assembly can be oriented from the surface to guide the borehole on a directional course. The greater the bend's angle, the greater the tendency for the borehole to change inclination and/or direction. The toolface is the direction of the drilling assembly's angle. A bent mud motor housing provided this directional control.

The direction and inclination of the borehole are controlled by turning the toolface in the desired direction. In general, when the toolface is turned, or oriented, to the high side of the hole (that is, the direction of the hole) the maximum amount of angle is built and no change in hole direction results.

When the toolface is turned 90 deg from high side a turn occurs with no change in deviation angle. When the toolface is turned 45 deg from high side, the hole builds angle and turns in equal amounts. Likewise, when it is turned 135 deg from high side, a drop in angle is concurrent and equal to a change in direction. Formation characteristics, hole conditions and drilling mechanics influence the performance of drilling assemblies downhole.

Snake-like pattern

When drilling horizontally, the small, limber assembly was affected by gravity and tended to drop angle. On the first horizontal leg a 30 ft (½ deg) bent motor housing was used initially, with the toolface pointed straight up to counteract gravity.

However, the small deflection of this housing was not enough to maintain directional control when irregularities in the coal seam were encountered. For example, when the drilling assembly hit hard areas in the seam the wellbore was deflected into excessive trends of angle build or angle drop. The directional control offered by the 30-ft housing was insufficient to correct the trend before the borehole left the coal seam.

To remedy these problems, a 45-ft (¾ deg) bent motor housing was made up in the assembly for greater directional control. However, because this greater deflection was more than that required to counteract gravity, orienting the tool face straight up would have made the borehole build angle instead of maintaining a horizontal path.

A compromise was necessary to counteract gravity and maintain good directional control. Therefore, the toolface was oriented approximately 45 deg to the right or left of the high side of the hole. This meant that while upward deflection counteracted gravity, a concurrent right or left hand turn developed. To maintain a relatively straight path, it was necessary to compensate for such turns by orienting the toolface 90 deg in the direction opposite the turn. This procedure produced a smooth, snake-like pattern characteristic of the horizontal boreholes.

Drilling Equipment and Circulation System

The directional and horizontal boreholes were drilled from a Reed rotary blasthole rig. Unlike standard oilfield rigs—where drill string weight is used in making hole—the blasthole rig is designed to exert a controlled downward force on the pipe to supplement bit penetration.

A 2⅞-in.-dia downhole mud motor and a 3-in. Christensen drill bit were used to drill both the directional and horizontal holes. A mud motor converts the force of water or drilling mud circulated through a wellbore into rotational power to turn the drill bit. When a mud motor is not used, the drill pipe is rotated to make hole. Deflection was accomplished through the use of 30-ft (½ deg) or 45-ft (¾ deg) bent housings on the downhole motor.

A magnetic single shot instrument, run in a muleshoe orienting sub, was used for surveying. The instrument was isolated from magnetic interference of the drill string by a 50 ft stainless steel drill rod run directly above it.

The single shot instrument uses a film disc to photograph a compass, an angle unit and a scribe line that denotes toolface setting. The survey tool is run inside the drill pipe to the bottom of the hole and retrieved on a wireline. Survey data is gathered by reading the developed film disc.

Fresh water was circulated through the boreholes to carry cuttings to the surface. In most oilfield drilling situations drilling mud is used, but it was unsuitable for the Emerald project since it would reduce the permeability of the coalbed and make degasification difficult or impossible. ■

speed and precision of future horizontal drilling for coalbed degasification. These techniques include the open-hole sidetrack and the compensatory orientation of the toolfsce.

Directional control in drilling pilot holes can be improved through the use of a larger oilfield-size drilling assembly, rather than the small 2⅞-in. assembly used in the project. However, economic considerations might make this impractical in some situations.

An advance in survey instrumentation that would eliminate the survey downtime and blind drilling experienced at the Emerald mine is currently under development. Modifications to the existing Eastman Whipstock Directional Orientation Tool (DOT) will enable the instrument to measure all angles of deviation from vertical, making the tool useful for drilling high-angle and horizontal boreholes.

Unlike the magnetic single shot instrument that was used in the project, the all-angle DOT will provide a continuous picture of hole direction, toolface orientation and deviation from vertical as they occur during horizontal drilling. Since this information will be transmitted via wireline to the surface, the downtime involved in retrieving the single shot instrument from the hole and, developing and interpreting the photograph would be eliminated.

In addition, the continual flow of downhole information provided by the Eastman Whipstock DOT will allow directional corrections to be made more quickly and accurately. These capabilities are especially valuable when attempting to maintain well paths within the narrow limits Of seams.

It is reasonable to estimate that horizontal degasification holes can be routinely drilled from the surface to distances of 3,000 ft in two weeks or less when the proper directional control techniques are implemented and the optimum drilling and surveying equipment are used.

Status of Emerald project

Dewatering of the coalbed is currently underway at the Emerald mine project site. No estimate has yet been made as to when this operation will produce sufficient quantities of water to allow economical degasification to begin. It is believed that ample quantities of gas can eventually be removed from the seam and that the project will confirm the overall feasibility of directional drilling as an alternative method for coalbed degasification. ■